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A regional 1.92 Ga tectonothermal episode in Ostrobothnia, Finland: Implications for models of Svecofennian accretion

Ian S. Williams[a,*], R.W. Roye Rutland[a], Jukka Kousa[b]

[a] Research School of Earth Sciences, The Australian National University, Canberra, ACT 0200, Australia
[b] Geological Survey of Finland, Regional Office for mid-Finland, P.O. Box 1237, FIN-70211 Kuopio, Finland

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ABSTRACT

The mostly metasedimentary Svecofennian Western Pohjanmaa belt in Ostrobothnia, Finland, can be divided into two stratigraphic groups separated by a major unconformity that reflects deformation following regional metamorphism. The western Lappfors group, interpreted as a Svionian basement complex, has strong W-trending folding and aeromagnetic signatures that contrast with the overlying eastern Evijärvi group, interpreted as lower Bothnian, which has more open N-trending folding and magnetic patterns. Several lines of evidence date the unconformity at ~1.92 Ga. Detrital zircons from two samples of Lappfors group metasediment, and a sample of the basal Nivala gneisses in the Eastern Pohjanmaa belt, have 1.92–1.91 Ga post-depositional low-Th/U metamorphic overgrowths. The maximum deposition age of the Lappfors sedimentary protoliths, based on detrital zircon ages, is between ~1.99 and ~1.95 Ga. Three samples of Bothnian sediments lack pervasive ~1.91 Ga overgrowths, instead having a variety of detrital zircons as young as ~1.95–1.91 Ga, reflecting recycling of the underlying basement complex. The maximum deposition age of the Bothnian sedimentary protoliths is inferred to be ~1.91 Ga. The Niska granitoid, which intrudes the Evijärvi group and is deformed only by the younger tectonic episode affecting that sequence, has a zircon age of 1896 ± 6 Ma. That episode, which established the present relationships between basement and cover, is dated by ~1.88 Ga metamorphic zircon overgrowths in both the Svionian and Bothnian samples, and by 1878 ± 4 Ma metamorphic monazite from a metasediment from the Savo belt, east of the Nivala district. The post-1.91 Ga volcanic sequences of the Svecofennian Province are unlikely to represent arc accretion. The Svionian metamorphic sequences are probably the remnants of a widespread marginal basin that formed between ~1.97 and 1.92 Ga, then was accreted to the craton during an Early Svecofennian (~1.92–1.91 Ga) orogenic phase, forming the basement on which the Bothnian volcano-sedimentary sequences were subsequently deposited.

1. Introduction

The Svecofennian Province in Sweden and Finland is characterised by widespread granitoids and more localised volcanic sequences, most of which were generated between 1.90 and 1.87 Ga. The volcanic sequences, notably in the Skellefte and Tampere districts (SD and TSB, Fig. 1) and also in Ostrobothnia (EPoB, Fig. 1), have usually been interpreted as volcanic arcs generated immediately above subduction zones and subsequently accreted to the continental margin (e.g. Park, 1985; Huhma, 1986; Patchett and Arndt, 1986; Gaál and Gorbatschev, 1987; Ekdahl, 1993; Lahtinen, 1994; Nironen, 1997). This arc-accretionary model is reflected in the terminology of the Bedrock map of Finland (Korsman et al., 1997), where only the "primitive arc complex (1.93–1.87 Ga)" (i.e. the Savo belt, immediately adjacent to the Archaean of the Karelian Domain, Fig. 1), is identified as older than 1.90 Ga.

The assumption that adjacent metasedimentary complexes are stratigraphically broadly equivalent to the volcanic sequences has been critical to this interpretation. Thus, the complexes of the Robertsfors Group and Vammala Migmatite belt (RG and VMB, Fig. 1), south of the Skellefte and Tampere volcanic belts, have been interpreted as fore arc or accretionary complexes (e.g. Weihed et al., 1992; Lahtinen, 1996; Kähkönen, 1999). The principal metamorphism and deformation within them has been assumed to be associated with arc accretion, and therefore to post-date at least part of the volcanic sequences. Major crustal-scale belts of high electrical conductivity associated with the metamorphic complexes have also been interpreted as reflecting collision during arc accretion (Korja, 1990; Korja et al., 1993).

There is increasing evidence, however, that the metamorphic complexes were deformed and metamorphosed before the volcanic

* Corresponding author. Fax: +61 2 6125 0738.
E-mail addresses: ian.williams@anu.edu.au (I.S. Williams), roye.rutland@anu.edu.au (R.W.R. Rutland), jukka.kousa@gtk.fi (J. Kousa).

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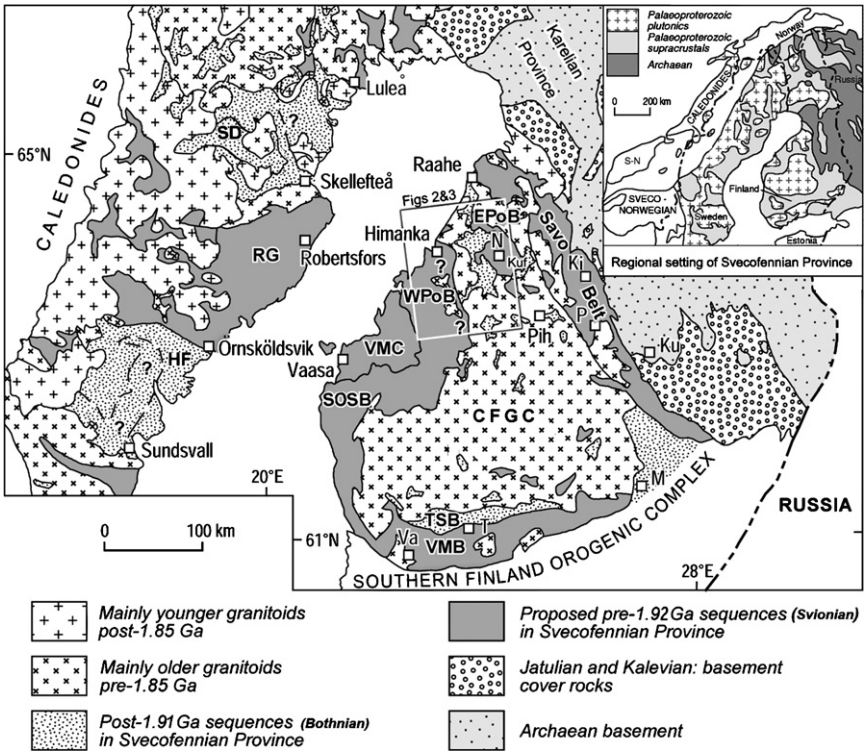

Fig. 1. Main elements of the central part of the Svecofennian Province and the adjacent Karelian Province (modified after Rutland et al., 2001b, Fig. 6). In Sweden: SD, Skellefte District; RG, Robertsfors Group; HF, Härnö Formation. In Finland: VMC, Vaasa Migmatite Complex; WPoB, Western Pohjanmaa belt; EpoB, Eastern Pohjanmaa belt; Kuf, Kuusaa Formation; SOSB, South Ostrobothnian Schist belt; CFGC, Central Finland Granitoid Complex; TSB, Tampere Schist belt; VMB, Vammala Migmatite belt. Townships: N, Nivala; Ki, Kiuruvesi; Ku, Kuopio; Pih Pihtipudas; M, Mikkeli; T, Tampere. Note that the area south of Himanka, indicated by question marks, is separated as the lower Bothnian Evijärvi group in this paper. The inset map indicates the regional setting in Fennoscandia, with national boundaries shown as dashed lines.

sequences of the Skellefte and Tampere districts were deposited, probably during the accretion of an older marginal basin (Rutland et al., 2001a,b). Direct dating of the metamorphism in the VMB at ~1.92 Ga has confirmed that the belt forms the basement of the TSB (Rutland et al., 2004). Further, Skiöld and Rutland (2006) have shown that the Robertsfors Group suffered early deformation and metamorphism at 1916 ± 5 Ma, indistinguishable in age from that in the VMB. Contrary to the arc-accretionary models, it has been concluded that the volcano-sedimentary sequences that post-date the ~1.92 Ga event in the Skellefte and Tampere districts were deposited in rift basins on older basement.

These results revive the essential elements of the hypothesis of Sederholm (1897, 1931) that an older 'Svionian Formation' (now dated as pre-1.92 Ga) was separated from a younger 'Bothnian Formation' by a great unconformity. The ~1.92 Ga tectonothermal event, which accreted the Svionian basin, has since been distinguished as an Early Svecofennian orogenic episode (Rutland et al., 2004). Accordingly, the terms Bothnian and Bothnian basin have been restricted to the younger sequences (such as the Skellefte and Tampere Groups), which were not strongly folded until ~1.88 Ga or later. This post-Bothnian orogenic event has usually been regarded as the only major phase of Svecofennian orogeny, but is now distinguished as a Middle Svecofennian orogenic episode (Skiöld and Rutland, 2006).

The distinction between Svionian and Bothnian sequences in the Skellefte and Tampere districts is aided by differences in both the style and orientation of the Early Svecofennian (pre-Bothnian) and Middle Svecofennian (post-Bothnian) structures. The older, Svionian, greywacke sequences (RG and VMB, Fig. 1) are characterised by an early metamorphism and recumbent deformation, and by superposed upright folding with north-easterly or northerly trends. In contrast, the post-1.92 Ga Bothnian volcanic and greywacke sequences in both districts (SD and TSB, Fig. 1) display relatively simple upright, easterly-trending cleavage folding of the Middle Svecofennian deformation, which appears to be related to shear zones cutting the earlier structures in the older basement sequence (Rutland et al., 2001a,b, 2004). As a consequence, the regional aeromagnetic maps reveal a strong contrast in magnetic patterns between the Svionian basement complexes and the overlying Bothnian volcano-sedimentary sequences. In the present paper we discuss evidence for similar, but previously unrecognised, basement–cover relationships in Ostrobothnia.

2. Ostrobothnia: regional geology

The major metasedimentary belt east of the Vaasa Migmatite Complex (VMC, Fig. 1) has been called the Bothnian belt (Kousa, 1997) or Bothnian Schist belt (Kousa and Lundqvist, 2000). In an attempt to harmonise the terminology of Finnish bedrock in terms of lithological–geographical subdivisions, Nironen et al. (2002) included both this metasedimentary belt and the volcano-plutonic complex further east in their Pohjanmaa belt. We shall therefore now distinguish these two main elements as the Western and Eastern Pohjanmaa belts (WPoB and EPoB; Fig. 1).

In previous tectonic syntheses that included Ostrobothnia, it has been assumed that no Svecofennian rock units were older than ~1.91 Ga and that the WPoB was involved in eastward subduction under the EPoB to generate the broadly contemporaneous volcano-plutonic complex of the EPoB (Ekdahl, 1993; Lahtinen, 1994; Nironen, 1997). These models were partly based on the presence of a meridional belt of high electrical conductivity in the WPoB that was recognised as a possible link between similar belts in the Robertsfors Group and Vammala Migmatite belt (Korja, 1990; Ekdahl, 1993). The latter are now dated as Svionian,